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REPORT OF CYCLOTRON FACILITY OPERATIONS OCTOBER 1, 1978 THROUGH--ETC(U)

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NRL Memorandum Report 4146

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Report of Cyclotron Facility Operations October 1, 1978 through September 30, 1979.

10 Rollon O. Bondelid

Cyclotron Applications Branch
Radiation Technology Division

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REPORT DOCUMENTATION PAGE		READ INSTRUCTIONS BEFORE COMPLETING FORM
1. REPORT NUMBER NRL Memorandum Report 4146	2. GOVT ACCESSION NO.	3. RECIPIENT'S CATALOG NUMBER
4. TITLE (and Subtitle) REPORT OF CYCLOTRON FACILITY OPERATIONS OCTOBER 1, 1978 THROUGH SEPTEMBER 30, 1979		5. TYPE OF REPORT & PERIOD COVERED Interim report on a continuing NRL problem.
		6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s) Rollon O. Bondelid		8. CONTRACT OR GRANT NUMBER(s) NIHNCI 1Y C0 4000-000 0 HO1-23A
9. PERFORMING ORGANIZATION NAME AND ADDRESS Naval Research Laboratory Washington, DC 20375		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS 61153N-12 RRO12-02-41 (Continues)
11. CONTROLLING OFFICE NAME AND ADDRESS Department of the Navy Office of Naval Research Washington, DC 22217		12. REPORT DATE December 28, 1979
		13. NUMBER OF PAGES 18
14. MONITORING AGENCY NAME & ADDRESS(if different from Controlling Office)		15. SECURITY CLASS. (of this report) UNCLASSIFIED
		15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)

Approved for public release; distribution unlimited.

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Neutron fields	Radioisotopes	Dosimetry
Neutron spectrum	Shielding	Fast neutrons
Weapons effects	Proportional counters	Radiation effects
Reactor materials	Linear energy transfer	Positive ion beams

(Continues)

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

This is the eighth in a series of quarterly reports summarizing the use of the Naval Research Laboratory Cyclotron Facility. During the twelve month period ending September 30, 1979 the cyclotron was used in support of ten research programs for a total 1690 hours of beam on target. These research programs are summarized in this report together with the details of beam time usage and facility engineering. No major operational problems were encountered this fiscal year. This report is presented as an annual report on cyclotron facility operation.

10. Program Element, Project, Task Area & Work Unit Numbers (Continued)

NRL Problem H00-01
H01-57
H01-79
H01-83
H01-94
H11-01
H11-07
H11-08

19. Key Words (Continued)

Neutron beams
Nuclear reactor
Neutron production
Non-military application
Cancer treatment

CONTENTS

REPORT OF CYCLOTRON FACILITY OPERATIONS
October 1, 1978 through September 30, 1979

I. Introduction

The Naval Research Laboratory Cyclotron Facility began operations as a cost center on October 1, 1977 and completed the first year of such operation on September 30, 1978. For fiscal year 1979 an estimate was made of the projected cost of operating the cyclotron facility and the number of hours users would require the cyclotron beam. These estimates are $273,200 and 2024 hours respectively, leading to a charge of $135 per hour. This report is the eighth in the current series of quarterly reports covering operation of the NRL Cyclotron Facility as a cost center from October 1, 1978 through September 30, 1979, and is thus treated as the second annual report in this series.

II. Beam Time Records

A. The Daily Record

Beam time charge accounting is accomplished using a simple method of coding information. At the end of each week the information is recorded in card images and stored on the disc file of the Systems 32/55 data acquisition computer located in the Cyclotron Facility for later recall and summarization. Figure 1 in the first report of this series is a sample of a beam time code sheet. The method of using this form was also described in the first report.

B. Computer Readout

Tables 1 through 4 show the collated data from the beam time card images.

Table 1 shows the beam time use by program and month. Outage is listed as a point of interest. This table is submitted to the NRL budget branch at the end of each month. Proper charges can then be recorded against the using program and credited to the cyclotron cost center.

Table 2 shows the summary by program and particle. The lowest and highest energies for that particle used are also shown.

Table 3 shows the beam time summaries in various ways. Firstly, by program, secondly, by month and thirdly, by particle. Clearly, the table shows that the greatest user has been the MANTA program.

Table 4 is an overall summary of beam time which lists primarily the reasons for unscheduled outages. From this table we see the major problem source continues to be the power supplies of the cyclotron. However, the R. F. system of the cyclotron has developed problems which has caused some significant down time. Outage number 8, "Experimenters Equipment," is included in total beam-on time, but it is not included as cyclotron down time. The item, "Total Hours Available to Date," is the number of hours from 0000 hours October 1 through 2400

Note: Manuscript submitted November 9, 1979.

hours September 30. The NRL cyclotron schedule had originally been planned for operating two 8-hour shifts per day for six days per week, holidays and scheduled engineering periods excluded. The utilization factor is the total scheduled time divided by this planned schedule.

III. Engineering and Maintenance

A. Cyclotron

The personnel protection interlock system, which is integrated with personnel and equipment protection safeguards, has undergone development. Changes consisted principally of replacement of an electrometer and precise adjustment of ion chamber amplifiers. With the installation of three meters to read electrical values and relocation of some circuit components, the time required for final calibration of the entire neutron monitor and control circuitry can be cut in half.

Most of the cyclotron magnet power supply designs are based upon engineering principles which were considered good 15 years ago when they were constructed. With the great emphasis on the reliable operation of these power supplies, they are undergoing in-house development designed to update control circuits to improve regulation, and to completely rebuild subsystems for improved reliability and increased load capability.

A chemical target holder and its associated components were fabricated for radioisotope production. The resulting radioisotopes can be employed for nuclear gauging, activation analysis, tracer techniques and nuclear medicine. The target assembly is of aluminum alloy construction with a hermetically sealed target chamber. Provisions are made for a 3 gallon per minute continuous flow of demineralized water across the back surface of the target holder to permit high beam currents and resulting in less time required for irradiations. The thickness of the aluminum target cover plate is designed to optimize production of the required isotope.

The R.F. system is a complex one, which is designed to be continuously self-tuneable from 7.5 to 23.5 MHz and to deliver up to 100 kilovolts to the cyclotron dee. There are several feedback loops for monitoring and controlling various voltage levels and rf phase relationships. These feedback loops consist of considerable amounts of sophisticated electronic circuitry and electromechanical interfacing. A recent development of the R.F. system included the addition of two components, which are vital for stability of the final stage RCA 4648 power amplifier tube (PA). They are the low impedance "screen by-pass" capacitor and the low impedance "grid swamping" resistance. The "screen by-pass" is a sandwiched structure formed by separating the screen grid contact surface from the flat upper surface of the PA socket by a 3-mil Kapton film. The 100-square-inch electrode surface yields a capacitance of about 40,000 pF. The criticality of the assembly can be more appreciated when one recognizes that the presence of one air bubble or a droplet of moisture between surfaces would allow detructive sparking that would totally destroy the function of the unit. Since the recent installation of that capacitor, there have been no incidents of capacitor damage and PA stability has been enhanced.

A design modification to existing indicator light panels, using small, low dc voltage incandescent lamps, has been implemented. The lamps have poor reliability and their cost has escalated to a level surpassing their effectiveness. This innovation, using inexpensive LED's, has restored high reliability and very low maintenance to indicator light panels. Less than 15 minutes is required for alteration, and the easy installation requires no tools.

B. MANTA Neutron Beam

The twin, flat ionization chambers, with 3-millimeter graphite-coated polystyrene walls and two 6-millimeter air gaps used in the absolute calibration of dose in the neutron beam, have been redesigned and installed between the neutron source and the collimating system of the microdosimetry and biological irradiations beam line. The chamber assembly is more compact, 3-centimeters closer to the beryllium target, and has reduced air gaps of 3-millimeters in length. The clear polystyrene plates have been retained, but their coating has been changed to a 500-angstrom thick film of vacuum deposited gold. Additional changes included the relocation of BNC connectors for compactness, and redesigned electronic contacts on both ion chambers and the high-voltage plate.

IV. Summary of Facility Use

A. MANTA

The National Cancer Institute (NCI) terminated the MANTA program effective June 30, 1979. Since the start of pilot studies in 1973, and the inception of clinical trials in 1977, over three-hundred patients participated in the neutron radiotherapy program.

A'. MANTA Dosimetry

Clinical research continued on whole-body dosimetry for open and wedged fields. These measurements were taken in a Rando-anthropomorphic phantom and in tissue-equivalent liquid phantoms by means of diodes, ion chambers, foil activation and thermoluminescent dosimeters. These four types of dosimeters were used in an attempt to separate whole-body dose into fast-neutron, thermal-neutron and gamma components.

Several runs were made for the ongoing experiment in collaboration with Dr. Richard Miller of Columbia University to compare the number of oncogenic cell transformations induced by neutrons with the number induced by x-rays. A comparison of the relative biological effectiveness and the oxygen enhancement ratio between the NRL-MANTA neutron therapy beam and the neutron therapy beam at the Franklin-McLean Institute (University of Chicago) was performed in collaboration with Professor Eric Hall of Columbia University.

A dosimetry intercomparison was performed with J. C. McDonald of the Sloan-Kettering Institute (SKI). This intercomparison involved a comparison of dose from ion chamber measurements by NRL and SKI, and a comparison of dose obtained from ion chamber measurements with that obtained from measurements using the SKI calorimeter. This work serves as a verification of ion chamber dosimetry against a method which can infer absorbed dose from measurements of fundamental physical quantities.

An experiment involving mouse tumor systems is being performed in collaboration with Professor Herman Suit of Massachusetts General Hospital and Harvard University. The object is to compare tumor response and normal tissue reactions for neutron treatment and x-ray treatment in conjunction with hypoxic sensitizers or hypobaric oxygen. Dosimetry for this experiment has been performed and five one-week runs have been made. Each run is a set of five-fraction treatments, one per day for five days. A new phantom with mouse holders has been designed and fabricated in order to treat a larger number of mice during one exposure for some runs planned for FY-80. Dosimetry on this new set-up has been performed and analyzed.

B. Radiation Interactions

The dependence of the degradation of transistors with neutron energy for the same neutron fluence has been studied. A comparison with theoretical calculations helps to distinguish between several damage functions used for silicon.

Dynamic random access memories (RAM) have been observed to develop soft errors caused by the passage of alpha particles through them. We postulated that alpha particles from the $^{28}Si(n,alpha)^{25}Mg$ reaction also should cause upsets. To investigate this effect, dynamic RAMS have been irradiated by high energy neutrons and protons while in the operating mode and have been observed to upset from both the "0" and the "1" states. The upsets are statistical and the affected cells can be reset and continue normal operation. The cause of the upsets is most probably a multi-MeV alpha particle created by (n,alpha), (p,alpha) or similar nuclear reactions. The alpha particle discharges either the storage capacitor, the floating bit line or the reference capacitor used by the sense amplifier.

A moderate size computer memory of 64K bytes requires 32 of the 16K RAMs. The mean fluence for one upset in the memory then drops from say 2×10^8 n/cm^2 to 6×10^6 n/cm^2. If a 90% confidence of no upset is required, the acceptable neutron fluence drops to 6×10^5 n/cm^2. These levels for upset are many orders of magnitude below the thresholds for commonly tested neutron damage. As volume and critical charges are further reduced, the radiation problem will increase very rapidly. We intend to study advanced devices such as 64K RAM's in neutron and proton environments. Our results attracted wide interest at the July Radiation Effects Conference in Santa Cruz.

B'. Neutron Spectra

Data were acquired for the (n, charged particle) spectrum produced by the neutron beam in air. A strong peak due to deuterons passing through feed-throughs in the beryllium target assembly was identified and eliminated with shielding. A remotely controlled assembly for locating the detector at distances of 10 cm to 110 cm from the target was installed. This assembly enables the identification of fluxes from the Al end plate of the target assembly to be followed in air and separated from the flux produced in air.

Si solid state detectors were exposed to the neutron beam to measure directly the spectrum of (n, charged particles). These measurements were made with and without a radiator (polyethelene) in front of the detector to evaluate a suggestion to use Si diodes for neutron dosimetry. A Si target, together with a solid-state particle identifier telescope, was exposed to our neutron beam to try to measure the charged-particle spectrum produced in Si electronic devices by the neutron beam.

C. Neutron Spectrometer

At the beginnning of this reporting period, it was demonstrated by Rossi-counter measurements, in and out of a large paraffin phantom, that significant changes in the incident neutron spectrum occur when an uncollimated neutron field irradiates a large hydrogenous body. Such spectral changes due to physical size imply significantly different biological responses to a neutron field for personnel with different body types. Even larger differences in neutron spectra and hence biological response can result from two other causes, and these are: the type of reaction producing the neutrons, and the amount and kind of material between the neutron source and the absorbing body. The dependence of biological response on the neutron spectrum poses severe problems in the area of neutron personnel dosimetry. It is worth noting at this point that the biological response of concern in the low-dose level regime is the development of radiation-induced cancer, especially leukemia, some years after the radiation exposure. Existing neutron personnel dosimeters in the DOD are not capable of detailing the changes in biological response that occurs as a function of the neutron spectrum internal to the absorbing body. Additionally, existing dosimeters are read-out some time after exposure. For those DOD personnel exposed to the most intense neutron fields, a neutron personnel monitor with instantaneous read-out and alarm features would appear to be the most desirable type to use. A neutron personnel monitor based upon a small, ruggedized Rossi counter was proposed during this reporting period as a possible solution to the neutron dosimetry problems that exist in the DOD. Work is continuing because on the basis of experimental data there appears to be a need for further research and development in this area.

During this reporting period, a significant flux of energetic light ions has been found to be associated with collimated beams of fast neutrons in air. During the past several months a good deal of time has been spent quantifying this light-ion-flux (LIF). It is clear that the LIF consists predominantly of protons knocked out of the walls of the hydrogenous collimators by the incident fast neutrons. Protons with energies as high as 35 MeV have been observed when the neutrons were produced by bombarding a thick Be + Al target with 42-MeV protons. This new finding, i.e., the LIF, has relevance in a number of research areas. Perhaps the information on this finding is most urgently needed in neutron cancer therapy. The LIF is of no value in therapy since it is dissipated in the first few mm of skin and subcutaneous tissue. However, it contributes to the late skin reactions which currently limit the neutron dose that may be given in therapy. The exact contribution of the LIF to the late skin reactions awaits definitive radiobiology experiments. The LIF can also cause confusion in other areas where collimated neutron beams are employed, as for example, the development of personnel dosimeters, in that not knowing that the LIF exists can lead to erroneous conclusions as to the sensitivity of a dosimeter. The results on the LIF will be presented at the APS Meeting in Knoxville, Tennessee, 18-20 October 1979. Additional presentations and information transfer to special groups are planned for the near future.

D. H + He in metals

To validate predicted depths and widths of implanted distributions of light ions in metal foils, as calculated by an inherited code, comparisons were made between predicted depths and widths with the equivalent ranges and range straggling appearing in recent literature. Good agreement was obtained between predicted depths and range values found in the literature, but there was considerable variation in the predicted widths and the equivalent range straggling values. Reconciliation of these differences was obtained by inserting an approximate formula for the range straggling into the program for each combination of host material and stopping projectile. Correspondence and discussion with Dr. James Ziegler of IBM led to increased understanding of continuing differences between calculated values of straggling for higher energy (10 - 100 MeV) projectiles and experimental measurements with a finite detector behind foil stacks. The calculated distribution corresponds to the width of an implanted distribution in an infinite medium, which may differ considerably from variation in ions detected with a finite angular acceptance. Measured profiles of implanted ions after correction for system resolution agree better with calculated straggling values (second moment) than do experimental values obtained by differentiating a range curve.

E. Neutron Weapons Monitors

Cyclotron runs were effected to continue the exploitation of CaF_2 - Thallium doped TLD's as personnel monitors exposed to mixed neutron-gamma fields. It was initially shown that when properly annealed these devices are useful as both casualty and radiation protection dosimeters. The objective is the development of a field device, using standard read-out equipment and techniques that yield both dose and the biological quality of the radiation exposure.

F. Neutron Damage

On-line measurements of the degradation of commercial LED devices bombarded with a 15-MeV median energy neutron beam have been obtained. During irradiation, the light output of an LED was recorded via a fiber optic link to an external area free of radiation where a photodiode amplifier viewed the fiber optic signal. The data for each LED can be described by one primary damage function and the amount of damage is rather strongly dependent on the As/P ratio for a specific type of LED.

A selected set of commercial LED devices was irradiated with 15-MeV median energy neutrons at liquid nitrogen, dry ice and room temperature. A marked difference in degradation of light output was noted as a function of temperature for the same neutron flux.

A set of commercial LED devices previously selected by Deep Level Transient Spectroscopy (DLTS) to have similar pre-irradiation characteristics have been irradiated by a 14-MeV neutron beam. Attempts to correlate pre-irradiation characteristics with post-irradiation (damage) electron trapping action are underway. So far, no such correlation has been found; however, it is hoped that increased sensitivity in DLTS measurements may give results.

G. Advanced Microdosimetry

As indicated under the Neutron Spectrometer Section of this report, the recently discovered light-ion flux (LIF) associated with collimated neutron beams can influence the results obtained in the Advanced Microdosimetry Program. Accordingly, some time was spent studying the LIF under this work unit. The discovery of the LIF and the techniques employed to quantify it have suggested the application of advanced microdosimetric methods to the area of plasma physics diagnostics. Code 6740 has been using the NRL Cyclotron to evaluate various existing diagnostic techniques to determine beam energy. Such techniques will be needed in the planned accelerator development proposed by this group. The techniques employed, activation and track detection, require lengthy study before being able to give an estimate of beam energy. If the scheme proposed as an outgrowth of the LIF study proves successful, then a value of the beam energy should be available within a few minutes from the start of the measurement. Such a rapid feedback of information should prove very useful in accelerator development. A special cyclotron target to evaluate the LIF-related approach to beam-energy determination has been designed and ordered.

During this reporting period the stainless-steel Rossi counter and some associated equipment were received, and preparatory work has begun using this novel instrument. A tantalum Rossi counter was also ordered during this reporting period, and it is scheduled to be delivered near the end of Calendar Year 1979.

Progress has been made during this reporting period in developing Systems computer software and hardware for acquiring and analyzing the Rossi-counter data. The implementation of the needed live-time correction feature on the Systems computer awaits final check out.

H. Neutron Effects

A number of cyclotron runs were taken to obtain neutron spectra. These used deuteron beams to produce intense neutron fluxes and proton beams to investigate the capabilities of producing a tailored neutron spectrum. These runs demonstrated our capabilities to produce either large fluxes of neutrons, such as needed for damage studies, or to tailor spectra to simulate neutron weapon threats.

A model for use in semi-empirical calculation of nuclear cross sections was further developed and used to calculate excitation functions of interest to various cyclotron users. The computer code for doing the calculations was modified to examine alpha-particle production in semiconductor devices. It was concluded that one cannot reduce the alpha particle production by large amounts by changing the material of the semiconductor (Si, GaAs). Some of these results are to be presented at the International Conference on Nuclear Cross Sections for Technology, Knoxville, Tennessee, 22-26 October 1979.

I. Data Acquisition System

During the year the data acquisition system was basically completed. It was used extensively in a number of experiments. The most use involved acquisition, display and printout of singles spectra, either particle-spectra, or gamma-ray spectra from various radioactive materials. The coincidence and time-of-flight modes were also used extensively. A variety of experiments used the magnetic tape writing and playback facilities. The ability to measure dead time on-line for each of the six ADC's was added. The scaler interface to the computer was basically designed and implemented. However, due to some incompatability between the SEL computer and the Canberra data buffer, a modification is required.

J. Heavy Ion Acceleration

Some computer runs, using the program DIAL, have been made for the heavy ions $^{14}N^{4+}$, $^{14}N^{5+}$, and $^{20}Ne^{6+}$. For calculations under the present running conditions (trim coils 1 and 3 = 0, and no harmonic coils available), the RMS field errors are quite large, though they decrease with increasing ion energy. Possibly the isochronous fields for a 100.5 MeV $^{14}N^{5+}$, and a 126.4 MeV $^{20}Ne^{6+}$ could be obtained under present conditions. With optimum running conditions (maximum of all trim coils equals 800 amps and harmonic coils working) there should be no trouble in obtaining the isochronous fields needed for obtaining the beams.

K. Other Users

Several bombardments were carried out for the production of medical radioisotopes for a program conducted by Dr. R. Kessler of the National Institutes of Health. Beam time was provided to code 6740 to evaluate methods of determining proton beam energy.

V. Accounting

Estimates made at the beginning of fiscal year 1979 were for a total beam time of 2024 hours in support of the various programs. The total budget required to support this beam time was estimated to be $273,200. The actual beam time use during this fiscal year was 1690 hours which represents a cost transfer of $228,150. The job order status report through September 30 showed total costs of $249,300. The difference of $21,150 represents a cost overrun in the operation of the cost center. Although the MANTA program was terminated on June 30 and was no longer providing income to the cost center, other programs increased in activity and cyclotron use did not drop by a large amount (see Table 3). Cyclotron usage was 17 percent under the predicted usage, mostly because of the termination of the MANTA program; however, cyclotron costs were 9 percent under predicted costs.

Table 5 shows a list of purchases required for Cyclotron Facility operation. The table is self explanatory.

VI. Conclusion

The NRL Cyclotron Facility continues to operate effectively as a cost center. Costs are reasonably close to matching income and, except for the termination of the MANTA program, the use of the facility is not far from that which was predicted at the start of the fiscal year.

Report Assembled by R. Bondelid

Contributors: R. Allas
L. August
L. Beach
C. Davisson
G. Miller
E. Petersen
P. Shapiro

TABLE I

BEAM TIME SUMMARY BY PROGRAM AND MONTH

CYCLOTRON APPLICATIONS BRANCH SUMMARY OF BEAM TIME
FY-79 SEPTEMBER 30, 1979

PROGRAM	MONTH	BEAM TIME	AT COST	OUTAGE
MANTA 66H01-23A	OCTOBER	158.6 HOURS	$ 21411	9.4 HOURS
	NOVEMBER	113.1 HOURS	$ 15269	10.5 HOURS
	DECEMBER	128.6 HOURS	$ 17361	10.3 HOURS
	JANUARY	129.7 HOURS	$ 17510	1.9 HOURS
	FEBRUARY	108.9 HOURS	$ 14702	2.5 HOURS
	MARCH	109.3 HOURS	$ 14756	17.5 HOURS
	APRIL	120.1 HOURS	$ 16214	25.3 HOURS
	MAY	95.9 HOURS	$ 12947	7.7 HOURS
	JUNE	58.1 HOURS	$ 7844	2.3 HOURS
	SUBTOTAL	1022.3 HOURS	$138014	87.4 HOURS
RADIATION INTER. 66H01-57	JANUARY	6.0 HOURS	$ 810	0.0 HOURS
	FEBRUARY	27.0 HOURS	$ 3645	3.0 HOURS
	MARCH	5.5 HOURS	$ 743	9.6 HOURS
	APRIL	15.5 HOURS	$ 2093	0.5 HOURS
	MAY	21.6 HOURS	$ 2916	7.4 HOURS
	JUNE	36.1 HOURS	$ 4874	0.0 HOURS
	JULY	2.5 HOURS	$ 338	0.0 HOURS
	SEPTEMBER	30.7 HOURS	$ 4145	0.0 HOURS
	SUBTOTAL	144.9 HOURS	$ 19564	20.9 HOURS
NEUTRON SPECTRUM. 66H01-79	NOVEMBER	6.0 HOURS	$ 810	2.0 HOURS
	DECEMBER	14.5 HOURS	$ 1958	0.0 HOURS
	MARCH	10.0 HOURS	$ 1350	0.0 HOURS
	JUNE	1.5 HOURS	$ 203	0.0 HOURS
	JULY	34.3 HOURS	$ 4631	2.5 HOURS
	AUGUST	66.8 HOURS	$ 9018	3.3 HOURS
	SUBTOTAL	133.1 HOURS	$ 17970	7.8 HOURS
H + HE IN METALS 66H01-83	OCTOBER	8.0 HOURS	$ 1080	0.0 HOURS
	SEPTEMBER	15.0 HOURS	$ 2025	0.0 HOURS
	SUBTOTAL	23.0 HOURS	$ 3105	0.0 HOURS
WEAPONS MONITORS 66H01-94	OCTOBER	0.5 HOURS	$ 68	0.0 HOURS
	NOVEMBER	2.3 HOURS	$ 311	0.0 HOURS
	DECEMBER	4.2 HOURS	$ 567	0.0 HOURS
	FEBRUARY	4.3 HOURS	$ 581	0.0 HOURS
	JULY	43.2 HOURS	$ 5832	0.5 HOURS
	AUGUST	12.7 HOURS	$ 1715	1.8 HOURS
	SEPTEMBER	31.1 HOURS	$ 4199	2.5 HOURS
	SUBTOTAL	98.3 HOURS	$ 13273	4.8 HOURS
NEUTRON DAMAGE 66H11-01	OCTOBER	1.0 HOURS	$ 135	0.0 HOURS
	DECEMBER	16.7 HOURS	$ 2255	0.0 HOURS
	JANUARY	12.2 HOURS	$ 1647	0.0 HOURS
	MARCH	30.1 HOURS	$ 4064	0.0 HOURS
	MAY	32.0 HOURS	$ 4320	0.0 HOURS
	JUNE	7.9 HOURS	$ 1067	0.0 HOURS
	JULY	17.3 HOURS	$ 2336	0.0 HOURS
	AUGUST	20.7 HOURS	$ 2795	0.0 HOURS
	SEPTEMBER	16.8 HOURS	$ 2268	1.0 HOURS
	SUBTOTAL	154.7 HOURS	$ 20887	1.0 HOURS
ADVANCED MICRODOS. 66H11-07	JUNE	7.0 HOURS	$ 945	0.5 HOURS
	JULY	10.5 HOURS	$ 1418	2.0 HOURS
	AUGUST	31.4 HOURS	$ 4239	2.5 HOURS
	SUBTOTAL	48.9 HOURS	$ 6602	5.0 HOURS
NEUTRON EFFECTS 66H11-08	OCTOBER	1.0 HOURS	$ 135	0.0 HOURS
	NOVEMBER	4.5 HOURS	$ 608	0.0 HOURS
	JANUARY	27.7 HOURS	$ 3740	0.0 HOURS
	SUBTOTAL	33.2 HOURS	$ 4483	0.0 HOURS
	SEPTEMBER	12.0 HOURS	$ 1620	0.0 HOURS
OTHER USERS USERS	AUGUST	4.6 HOURS	$ 621	0.0 HOURS
	SEPTEMBER	15.0 HOURS	$ 2025	9.8 HOURS
	SUBTOTAL	19.6 HOURS	$ 2646	9.8 HOURS
	TOTAL	1690.0 HOURS	$228164	136.7 HOURS

TABLE II

BEAM TIME SUMMARY BY PROGRAM AND PARTICLE

CYCLOTRON APPLICATIONS BRANCH SUMMARY OF BEAM TIME
FY-79 SEPTEMBER 30, 1979

PROGRAM	PARTICLE	BEAM TIME	ENERGY RANGE-MEV	
MANTA 66H01-23A	DEUTERON	1022.3 HOURS	35	35
RADIATION INTER. 66H01-57	PROTON	17.0 HOURS	35	40
	DEUTERON	97.9 HOURS	16	35
	HELIUM-3	26.0 HOURS	22	22
	ALPHA	4.0 HOURS	70	70
	SUBTOTAL	144.9 HOURS		
NEUTRON SPECTRUM. 66H01-79	PROTON	40.6 HOURS	42	42
	DEUTERON	92.5 HOURS	16	35
	SUBTOTAL	133.1 HOURS		
H + HE IN METALS 66H01-83	PROTON	15.0 HOURS	10	40
	ALPHA	8.0 HOURS	36	36
	SUBTOTAL	23.0 HOURS		
WEAPONS MONITORS 66H01-94	PROTON	36.6 HOURS	8	50
	DEUTERON	21.2 HOURS	16	35
	HELIUM-3	40.5 HOURS	22	22
	SUBTOTAL	98.3 HOURS		
NEUTRON DAMAGE 66H11-01	DEUTERON	154.7 HOURS	22	35
ADVANCED MICRODOS. 66H11-07	DEUTERON	48.9 HOURS	35	35
NEUTRON EFFECTS 66H11-09	PROTON	27.7 HOURS	16	18
	DEUTERON	5.5 HOURS	35	35
	SUBTOTAL	33.2 HOURS		
	PROTON	12.0 HOURS	15	20
OTHER USERS USERS	DEUTERON	1.8 HOURS	16	16
	ALPHA	17.8 HOURS	70	70
	SUBTOTAL	19.6 HOURS		
	TOTAL	1690.0 HOURS		

TABLE III

BEAM TIME TOTALS BY PROGRAM, MONTH AND PARTICLE

CYCLOTRON APPLICATIONS BRANCH SUMMARY OF BEAM TIME
FY-79 SEPTEMBER 30, 1979

PROGRAM	START UP TIME	BEAM ON TARGET	TOTAL TIME	COST	OUTAGE	SCHEDULED TIME	% ON
MANTA	229.4 HOURS	792.9 HOURS	1022.3 HOURS	$ 138011	87.4 HOURS	1109.7 HOURS	92.1
RADIATION INTER.	29.0 HOURS	115.9 HOURS	144.9 HOURS	$ 19562	20.9 HOURS	165.8 HOURS	87.4
NEUTRON SPECTRUM.	18.1 HOURS	115.0 HOURS	133.1 HOURS	$ 17969	7.8 HOURS	140.9 HOURS	94.5
H + HE IN METALS	6.5 HOURS	16.5 HOURS	23.0 HOURS	$ 3105	0.0 HOURS	23.0 HOURS	100.0
WEAPONS MONITORS	15.3 HOURS	83.0 HOURS	98.3 HOURS	$ 13271	4.8 HOURS	103.1 HOURS	95.3
NEUTRON DAMAGE	21.0 HOURS	133.7 HOURS	154.7 HOURS	$ 20885	1.0 HOURS	155.7 HOURS	99.4
ADVANCED MICRODOS.	4.5 HOURS	44.4 HOURS	48.9 HOURS	$ 6602	5.0 HOURS	53.9 HOURS	90.7
NEUTRON EFFECTS	8.0 HOURS	25.2 HOURS	33.2 HOURS	$ 4482	0.0 HOURS	33.2 HOURS	100.0
	2.5 HOURS	9.5 HOURS	12.0 HOURS	$ 1620	0.0 HOURS	12.0 HOURS	100.0
OTHER USERS	5.3 HOURS	14.3 HOURS	19.6 HOURS	$ 2646	9.8 HOURS	29.4 HOURS	66.7
TOTALS	339.6 HOURS	1350.4 HOURS	1690.0 HOURS	$ 228155	136.7 HOURS	1826.7 HOURS	92.5

MONTH	BEAM TIME	OUTAGE	SCHEDULED TIME	% ON
OCTOBER	169.1 HOURS	9.4 HOURS	178.5 HOURS	94.7
NOVEMBER	125.9 HOURS	12.5 HOURS	138.4 HOURS	91.0
DECEMBER	164.0 HOURS	10.3 HOURS	174.3 HOURS	94.1
JANUARY	175.6 HOURS	1.9 HOURS	177.5 HOURS	98.9
FEBRUARY	140.2 HOURS	5.5 HOURS	145.7 HOURS	96.2
MARCH	154.9 HOURS	27.1 HOURS	182.0 HOURS	85.1
APRIL	135.6 HOURS	25.8 HOURS	161.4 HOURS	84.0
MAY	149.5 HOURS	15.5 HOURS	165.0 HOURS	90.6
JUNE	110.6 HOURS	2.8 HOURS	113.4 HOURS	97.5
JULY	107.8 HOURS	5.0 HOURS	112.8 HOURS	95.6
AUGUST	136.2 HOURS	7.6 HOURS	143.8 HOURS	94.7
SEPTEMBER	120.6 HOURS	13.3 HOURS	133.9 HOURS	90.1
TOTALS	1690.0 HOURS	136.7 HOURS	1826.7 HOURS	92.5

PARTICLE	BEAM TIME	ENERGY RANGE-MEV		OUTAGE	SCHEDULED TIME	% ON
PROTON	148.9 HOURS	8	50	4.8 HOURS	153.7 HOURS	96.9
DEUTERON	1444.8 HOURS	16	35	112.0 HOURS	1556.8 HOURS	92.8
HELIUM-3	66.5 HOURS	22	22	10.1 HOURS	76.6 HOURS	86.8
ALPHA	29.8 HOURS	36	70	9.8 HOURS	39.6 HOURS	75.3
TOTALS	1690.0 HOURS			136.7 HOURS	1826.7 HOURS	92.5

TABLE IV

BEAM TIME SUMMARY TO SHOW CYCLOTRON PERFORMANCE

CYCLOTRON APPLICATIONS BRANCH SUMMARY OF BEAM TIME
FY-79 SEPTEMBER 30, 1979

CYCLOTRON OPERATIVE	HOURS	HOURS
CYCLOTRON START-UP	339.6	
BEAM ON TARGET	1350.4	
TOTAL BEAM-ON TIME		1690.0
UNSCHEDULED OUTAGE		
1 ION SOURCE	13.2	
2 VACUUM SYSTEM	6.6	
3 DEMINERALIZED WATER	1.7	
4 POWER SUPPLIES	64.5	
5 R. F. SYSTEM	32.0	
6 ELECTRICAL COMPONENTS	5.0	
7 MECHANICAL COMPONENTS	12.9	
8 EXPERIMENTERS EQUIPMENT	3.7	
9 RADIOLOGICAL SAFETY	0.8	
TOTAL OUTAGE	140.4	
TOTAL SCHEDULED TIME		1826.7
PERCENT BEAM AVAILABLE (ITEM 8 INCLUDED IN BEAM-ON TIME)		92.5
TOTAL HOURS AVAILABLE TO DATE		8760.0
POSSIBLE SCHEDULED HOURS (2-SHIFTS 6-DAYS PER WEEK)		4864.0
UTILIZATION FACTOR, PERCENT		37.6

TABLE V

A LISTING OF PURCHASES REQUIRED FOR CYCLOTRON FACILITY OPERATION

CYCLOTRON APPLICATIONS BRANCH SUMMARY OF PURCHASES
FY-79 SEPTEMBER 30, 1979

CONTROLS ARE, PROGRAM OPERATIONS   MONTH ALL   PRICE 0   CATEGORY A ALL

ITEM	COST	PROGRAM	MONTH	CARD	STUB NO.	CATEGORY A
IBM KEYPUNCH	$ 1632	OPERATIONS	OCTOBER	1	13 *	DATA SYSTEM
VYDEC	$ 6391	OPERATIONS	OCTOBER	2	14 *	DATA SYSTEM
SEL SOFTWARE	$ 635	OPERATIONS	OCTOBER	3	15 *	DATA SYSTEM
STRAYNER FILTER	$ 3492	OPERATIONS	OCTOBER	5	25 *	H-2-O SYSTEM
PLASTIC TOP	$ 5	OPERATIONS	OCTOBER	6	37	MATERIALS
DISC CARTRIDGE	$ 192	OPERATIONS	OCTOBER	7	50 *	DATA SYSTEM
GASKET MATERIAL	$ 56	OPERATIONS	OCTOBER	8	57 *	ION SOURCE
XEROX TRANSPARENCIES	$ 64	OPERATIONS	OCTOBER	9	64 *	MATERIALS
DISPATCH CASE	$ 10	OPERATIONS	NOVEMBER	11	77	MATERIALS
DISPATCH CASE	$ 10	OPERATIONS	NOVEMBER	12	78	MATERIALS
DEUTERIUM	$ 255	OPERATIONS	NOVEMBER	14	109 *	MATERIALS
POWER DEVICES	$ 2617	OPERATIONS	NOVEMBER	15	112 *	POWER SUPPLIES
CARTRIDGE REGENERATION	$ 1484	OPERATIONS	DECEMBER	16	120 *	H-2-O SYSTEM
FILTER MEMBRANE	$ 308	OPERATIONS	DECEMBER	17	121 *	H-2-O SYSTEM
CARTRIDGE REGENERATION	$ 1224	OPERATIONS	JANUARY	19	156 *	H-2-O SYSTEM
CUPS	$ 16	OPERATIONS	FEBRUARY	21	221 *	MATERIALS
XEROX TRANSPARENCIES	$ 66	OPERATIONS	FEBRUARY	22	220 *	MATERIALS
ALUMINUM FOIL	$ 6	OPERATIONS	FEBRUARY	23	233 *	MATERIALS
B P ENERGOIL	$ 256	OPERATIONS	FEBRUARY	24	245 *	VACUUM SYSTEM
CHOPPER	$ 286	OPERATIONS	MARCH	26	253 *	POWER SUPPLIES
CAMERA REPAIR	$ 50	OPERATIONS	MARCH	27	291 *	MATERIALS
DEUTERIUM	$ 255	OPERATIONS	MARCH	28	298 *	ION SOURCE
VACUUM REPAIR KIT	$ 50	OPERATIONS	MARCH	29	299 *	VACUUM SYSTEM
IONIZATION TUBES	$ 420	OPERATIONS	MARCH	30	297 *	VACUUM SYSTEM
VACUUM REPAIR KIT	$ 50	OPERATIONS	APRIL	31	310 *	VACUUM SYSTEM
THERMOCOUPLE TUBE	$ 240	OPERATIONS	APRIL	32	309 *	VACUUM SYSTEM
MULTIDRAFT	$ 18	OPERATIONS	APRIL	33	316 *	MATERIALS
CARTRIDGE REGENERATION	$ 1224	OPERATIONS	APRIL	38	333 *	H-2-O SYSTEM
CHOPPER	$ 200	OPERATIONS	APRIL	39	342 *	POWER SUPPLIES
MICROFICHE READER	$ 307	OPERATIONS	MAY	40	353 *	MATERIALS
UPPER PART FOR READER	$ 9	OPERATIONS	JUNE	42	385 *	MATERIALS
TUBING	$ 76	OPERATIONS	JULY	44	443 *	ION SOURCE
DRAFTING PENS	$ 11	OPERATIONS	AUGUST	45	469 *	MATERIALS
O-RINGS	$ 125	OPERATIONS	AUGUST	46	472 *	ION SOURCE
MULTIMETER	$ 1810	OPERATIONS	AUGUST	51	533 *	ELECTRONICS
GAUGE CONTROLLER	$ 650	OPERATIONS	AUGUST	52	534 *	VACUUM SYSTEM
HEATERS	$ 1091	OPERATIONS	AUGUST	55	590 *	VACUUM SYSTEM
TANTALUM	$ 480	OPERATIONS	AUGUST	56	602 *	ION SOURCE
FILTER MEMBRANES	$ 528	OPERATIONS	AUGUST	57	603 *	H-2-O SYSTEM

TOTAL = 26599